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Published four times a year: in November, January, March and May
By W. G. WHITMAN, SALEM, MASS.
Entered as second class matter Nov. 6, 1916, at Salem, Mass., under the Act of March 3, 1879

$1.50 a year
40c a copy

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VOLUME 9
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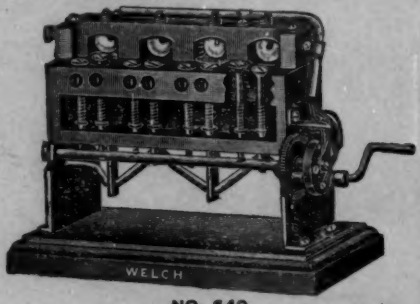

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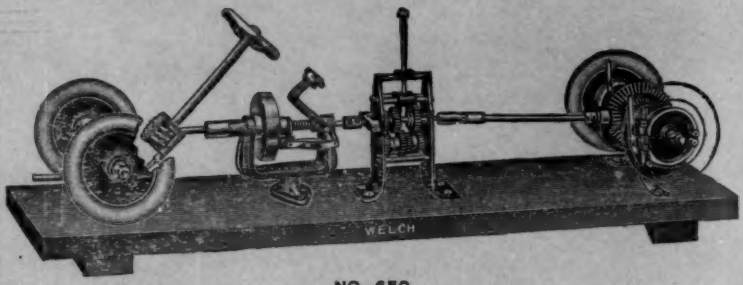

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General Science Quarterly

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Vol. IX MAY 1925 No. 4

Reorganization of the Biology Course to Meet the Needs of Democracy.

ELLIOT R. DOWNING.
The University of Chicago, The School of Education.

THE recent figures given by the Commissioner of Education in regard to the enrollment in the biological sciences in the high schools of the United States, are somewhat startling in their character. In the twelve year period, from 1910 to 1922, the percentage of high school students enrolled in botany has declined from 16.34 per cent to 3.82 per cent, in zoology from 8.02 per cent to 1.53 per cent, a drop of about 80 per cent. The enrollment in biology was not recorded until 1915, at which time it was 6.19 per cent, in 1922 it was 8.38 per cent, a gain of 35.6 per cent in seven years. In the twelve-year period referred to, agriculture made a gain of less than 10 per cent, Apparently the biological sciences have lost ground when the enrollment is expressed in terms of the total enrollment.

In the actual number enrolled there has been no loss, for the high school enrollment has increased so rapidly that, in spite of the decline in percentage of the total enrollment, the numerical enrollment in science classes has increased. From 1890 to 1920 the high school enrollment increased 854 per cent,—130 per cent in the decade from 1910 to 1920.

The apparent decline is due to the rapid increase in the enrollment in certain subjects, such as domestic science and commercial subjects. On the whole, science is holding its own remarkably well. The net loss to science, including domestic science, in the twelve year period is 4.28 per cent of the total enrollment. In the same period, history and civics lost 6.60 per cent, modern languages 6.80 per cent, Latin 21.53 per cent, mathematics 26.23 per cent, English 37.60 per cent.

During this same period there has been a marked change in the character of the text books for use in high schools in the biological sciences. Almost no new zoologies have appeared, comparatively few botanies, but there is a host of new texts in biology.

The most striking difference between the treatment of subject matter in the biologies and in the old botany and zoology texts is that in the former a great deal more space is devoted to the principles of the science. When an author plans a course in botany or zoology he is prone to think in terms of the materials to be studied, but when he is planning a course in biology he is much more inclined to think in terms of the principles to be presented. From a quarter to a half of the space in the biologies that have appeared within the last ten years is devoted to important principles, while in recent botanies and zoologies the presentation of principles is exceedingly rare. The great bulk of such books, as a rule more than 95 per cent, is occupied with a statement of a mass of detailed fact.

Whether there is any correlation between the decline in the percental enrollment in botany and zoology and this presentation of a mass of unorganized facts in the text books, it is impossible to determine. Certainly, however, the new organization in terms of general principles, which is coming into vogue in the biology texts, is a reaction which may make the subject much more attractive.

Pedagogically it seems a move in the right direction. In these days of crowded curricula a subject can only justify its place in the course of study by presenting material that is really worthwhile in life situations. When we come to a perplexity the solution of which demands the application of what we have learned, the process is always a deductive process. We ransack our minds for a general principle that will apply in the specific difficulty. It is only, then, as we organize our knowledge in terms of general principles that it comes to have widest application in life.

Therefore, we must select for the subject matter of our biology course those principles that are of largest significance in social situations. At present we have little or no fact-knowledge upon which to solve this problem of selection. Caldwell and Finley have made one study that is a contribution to

this problem. They selected seventeen newspapers, distributed widely over the country, read a month's issues carefully, then clipped and classified all the articles dealing with biological materials. The ability to read intelligently what is appearing in the papers is one criterion for judging the proper content for a biological course. Similar studies are going on, using as a basis for the study some of the magazines, such as the Literary Digest. We need surveys of various social groups—doctors, housewives, farmers, and so on—to determine what biological principles are most frequently needed by them in their daily activities. In time such studies will afford us an actual fact basis for determining what biological principles are of largest social value. At present we must rely largely upon the wisdom of the text-book writer, supplemented by the teacher's appreciation of the local needs of the community which he is serving.

The results derived by giving standardized tests to high school pupils, show that a disappointingly small percentage of the students have grasped fundamental concepts. The subject matter of these tests is usually taken from the materials common to the most widely used texts. It represents, therefore, the subject matter which, in the opinion of most authors, is of most importance. Powers finds in chemistry that the average student scores only a little over 50 per cent on his chemistry test. The author's Range of Information Test, covering science in general, is made up of words and phrases to define or explain which students must be familiar with important concepts in science. More than twenty high school science teachers, to whom it was submitted when first formulated, thought the average high school senior would score close to 100 per cent on it. The median score for seniors, based on over a thousand returns, is a little over 30 per cent. Studies based on a new test undergoing standardization, show that 60 per cent of the high school seniors in typical Chicago high schools think that all plants bear seeds; 70 per cent do not know that both plants and animals produce eggs; 85 per cent do not know that photosynthesis goes on only in green plants; 90 per cent are unfamiliar with the simple workings of Mendel's Law.

We are apparently trying to teach too much in our sciences. We should settle on a few principles of real value to the

pupil in life situations, and hammer these home until they are unforgettable. We must drill pupils on carrying these over into their practical applications; for knowledge does not of itself carry over, it remains subject matter to be used in school and has no connection with life, unless the teacher sees to it that the pupil is habituated to its use in life situations.

The biology course should be broken up into a few units, nine or ten for a year's work. Each of these should eventuate in the comprehension and application of one or more principles of prime importance to the student.

Each unit should have a challenging title or striking introduction, so as to interest the pupil from the outset. Each should deal with a problem that is vital to the students. Such unit topics as "Why We Eat Sunshine," "How a Breeder Produces a Record Breaking Milch Cow or Race Horse," are samples of the right kind of units. The former would eventuate in the comprehension of the law of the conservation of energy and its application to the human machine, including the wise choice of foods. The latter would give a knowledge of the laws of heredity and their application to human improvement.

But the acquisition of knowledge is only one of the important aims in our science teaching. As Dewey points out, science is quite as much a method as it is a mass of knowledge. One of the most important aims, if not the most important, is to teach pupils to think. It is a trite, though true saying, that high schools and colleges are training the future leaders of democracy. The individual and the nation are bound to be successful in proportion as they can think through the problems that confront them.

Science is peculiarly adapted to give training in this thought process. The student can be faced with many problems, small or great according to his capacity, each one of which requires in its solution the complete series of psychological processes that go into reflective thinking. He must use his own senses. He must analyze and synthesize his sense impressions to obtain the clear-cut percepts. He must discriminate by noting resemblances and differences. He must bring into correlation with present facts, past experiences. He must formulate his own guess as to the solution of the difficulty. He must experiment to prove or disprove his hypothesis. On the basis of all the

material which he has accumulated, he must reason to his own conclusion. It is not as easy in most other subjects for the pupil to think through a problematic situation from the bottom up. He cannot, for instance, collect his own facts in history. He rarely has, in literature, that wealth of past experience comparable to what he possesses in sciences because of his numerous nature contacts.

If we are going to train the pupil in the art of scientific thinking, some of the units or at least parts of units must be thrown into the problem or project form. I use the term project in the sense of a problem in the concrete, a problem whose answer is to be given in terms of an objective result.

Let the biology class undertake to free the local community of mosquitos or flies, to bring into bearing again a defunct orchard, to beautify the community by propagating and distributing, with directions for planting, ornamental shrubs and trees, or any such project, and the pupils are forced to face a real problem on which they can readily score themselves in terms of visible results.

Education is complete only when it results in action. We have grown so accustomed to regarding the school child as an empty vessel, the teacher as a receptacle of knowledge whose business it is to pour that knowledge into the child, that it is difficult for the science teacher to refrain from monopolizing the class time by instruction. The child should be permitted to learn through his own activity. The business of the instructor is to coach the pupil in his endeavor to acquire knowledge, to supervise his activities with a view to perfecting his technique of learning. Let the teacher then start the pupils on a project or problem, then merely stand on the sidelines to see that their thinking follows through in accordance with the rules of the game.

There is a third large value to be achieved in the teaching of biology, namely, to give pupils some appreciation of the values of science and of the self-sacrificing efforts of the great scientists. Some units, or at least parts of several units, should be so organized as to introduce historical and biographical material. To have pupils realize that science has grown because of the endeavors of many men, to have them appreciate the

persistent toil of Pasteur, even after he was crippled with paralysis, of Darwin, in spite of his invalidism, of Priestly, ostracized in his community because his achievements ran counter to community beliefs, is to force them to realize at what cost our present scientific knowledge has been achieved. It is eminently worth while to have high school pupils in the period of formative ideals learn of the struggles of some of these great discoverers, to help them see that the large values in life are not measured in terms of what one gets out of life, but rather in terms of what one puts into life.

Recent studies seem to indicate that our methods in the teaching of biology need large modification. Within the past few years, careful studies have been made of the relative merits of the lecture demonstration and the laboratory method of procedure. These have all shown, quite contrary to expectations, that as far as imparting knowledge is concerned, the lecture demonstration is superior to the laboratory method. It is true that on delayed tests the laboratory method seems to make a somewhat better showing, but the things that are retained by the laboratory method are the methods of performing the experiment, and what happens in the experiment, while on the items of most importance, namely, what the experiment is for and what it shows, the lecture demonstration method gives as good or better results than the laboratory method. Even in the development of ability to attack new problems and in the acquisition of laboratory technique, at least in its earlier stages, the lecture demonstration is apparently superior.

This means that we should substitute prepared dissections for those done by the students, and that we should use the projection microscope rather than individual compound microscopes. Such detailed studies of structure as were formerly conducted in the biological laboratory are largely disappearing at the high school level, but in so far as they are still needed, the demonstration method is without much question superior.

In place of the old structural studies, those dealing with the activities of animals, their habits and life histories are recognized now as much more worth while. Studies of children's interests show that the school child is primarily concerned with the identification of animals and plants and with their behavior;

they are not interested in structure, excepting as this is necessary to understand the activities. Furthermore, the studies of children's interests have shown that the chief groups of animals which evoke their attention are, in the order of their importance, birds, insects, and the common mammals, or children's pets. The corresponding plant groups are the wild flowering plants, the trees, and the vegetables, fruits and flowers of the garden. The subject matter of biology should deal therefore, pretty largely with the activities of these several groups.

New Life in Old Chemistry.

C. E. OSBORNE,
Head of Chemistry Department, Oak Park–River Forest High School, Oak Park, Illinois.

LAST summer it was my great privilege to drive some five thousand miles over the prairies, mountains and valleys of this great democracy where every man is a king, but where no man dares wear a crown. After traveling all afternoon over the dusty, gravel, unprotected roads of Indiana, toward evening there appeared before our vision a beautiful, silvery ribbon of hard road. Nature, free from unsightly signboards, was at her best. A neat, modest marker by the roadside said "Ohio." A traveler falls in love with Ohio at sight. We spent the night at Dayton and the next morning arrived in Columbus. Of course we saw the State University. We were impressed by three things: the spaciousness of the campus, the great number of buildings, and the neat, attractive appearance of it all. Although we later visited Yale, Princeton, Harvard, Johns Hopkins, Oberlin, and others, these impressions of Ohio State still linger.

At that time I did not dream I should be here today in the cause of a subject for which I have spent my life and am willing to be spent unstintingly. It is, therefore, an unusual pleasure to address you at this time as my co-workers in the teaching of character and chemistry. For my purpose, I have chosen as my subject, "New Life in Old Chemistry."

[1] Read before the Non-Biological Section, State Conference, Ohio State University, Columbus, Ohio, April 3, 1925.

Perhaps you have heard the story of the gentleman who killed a turtle in his backyard one summer afternoon, and to make sure of it, cut off the turtle's head. An hour later he returned, and in spite of the fact that he had severed the head from the body, the tail still wiggled. He explained the matter to a neighbor, who had called to see him, and a heated argument arose as to whether or not the turtle was really alive or dead. An old German friend happened along at this time, and they appealed to him to decide the question. "Now," said he, "led me see. You say you cut off der turdle's het aboud two o'clock, but his tail still viggles, und you vant me to decide whedder der turdle is alife or det. My obinion is, dat der turdle is det, but he don't know it."

I am not a pessimist. I do not believe that high school chemistry is dead. But as teachers, there are many ways in which we unintentionally are retarding the progress of high school chemistry and helping to kill it, and it is mandatory that these faults be corrected.

We deplore the lack of good teachers. It is not only true in the small high school, where one must teach several subjects, or perchance lead an orchestra, coach a football team and fill out his schedule with a class in chemistry, but it is far from ideal at the other extreme in a large city high school system, where a specialist in botany spends his life teaching physics, where another who has majored in mathematics is appointed to teach chemistry, and one who has spent seventeen years as head of a department of English is assigned to teach typewriting, shorthand and commercial geography. The attempt to teach the teachers how to teach chemistry is a progressive step worthy of our support. There is a vast difference between having a knowledge of chemistry and being able to impart that knowledge, but that one must first have that knowledge before he can impart it cannot be challenged. It is a shame that many new teachers must blunder along for years making the same mistakes, of which they could have been forewarned by teachers of experience before they began. More than ever before great business men recognize the necessity of training their salesmen how to sell. There is much of good salesmanship involved in good teaching.

The texts are too cumbersome. Several of recent date contain between six and seven hundred pages. It would take two years to cover this adequately. There is but one way to complete such a text,—to omit half of it, and that is not satisfactory. I cannot cover more than four hundred pages thoroughly, and am compelled during the second semester to omit the summary, exercises, and review questions at the end of each chapter. This also means that little time is spent on the metals, and the subject of organic chemistry is barely mentioned. It is unfortunate that the pupil who may never again study it should have this distorted view of the field of chemistry.

Progress is retarded by using a text not suited to your pupils. This is a matter which we cannot always control. The teacher of experience will adapt his text to his pupils, but the younger teacher is not so daring and confident. As scientists, we must face the facts. We must recognize the truth that probably fifty per cent of the pupils studying high school chemistry are juniors and have not studied physics. More than a quarter of a century ago, Dr. J. Alexander Smith, who probably had no superior as a university teacher of inorganic chemistry, said that "chemistry must be preceded by physics and must therefore be taught in the senior year." The committee recently appointed by the American Chemical Society to consider the correlation of high school and college chemistry suggested that we "encourage chemistry being placed in the senior year, after they have had a year of general science and a year of biological science, or physics, or both." Some progress has been made in this direction in the past thirty years. The course now taught in general science to our freshmen does a great deal to interest pupils in chemistry, and to help them to understand the physical phenomena involved in chemical changes. Our progress is retarded by the fact that the pupils have not had a year of physics. But as long as the mathematics and quantitative experiments in physics make the course so much more difficult than chemistry, conditions will not change. Many of my best pupils are juniors, and we cannot overlook the fact that four of the six winners of scholarships to Yale awarded by the American Chemical Society for the best essays in the national contest were won by pupils in the junior year.

For several years I have used a text written by high school teachers who should know the capacity of a high school pupil. Their explanations of chemical theory are impossible of comprehension by the pupils. I tell the pupils to read it, but that I do not expect them to understand it, and when they come to class I will try to tell them what the authors intend to say. The prestidigitator says, "The more you look the less you see." I say that the more you read of this theory, the less you know. It is said that the animal called the squid carries an ink-bag in his body, and when he is attacked and liable to capture, he muddies the water with this solution, and in the confusion escapes the enemy. I cannot think otherwise but that this particular author in these particular matters, plays the human squid.

Laboratory experiments that are too difficult and which give unsatisfactory results after reasonable care, especially if placed at the beginning of the course, do more harm than good. The second week, let the pupil find the percent of oxygen in the air by sticking a wire in a piece of phosphorus, inverting a eudiometer filled with air over water, and inserting the phosphorus on the wire. Let stand over night. Happen in the building about midnight, as I did, see the phosphorous catch fire, see the air expand due to the heat generated, and escape from the tube, and when it cools to room temperature the water takes the place of the overheated air, as well as the place of the consumed oxygen. When your conscientious pupil makes his measurements next day, wades through the mysterious application of Boyle's and Charles' law, including the correction for pressure of water vapor and differences of levels, gets thirty to thirty-five per cent of oxygen when he knows it should be twenty-one per cent, and to reward him for his painstaking effort you tell him this is not satisfactory and must be repeated with more care, you will have something to explain to him to get back his confidence in the accuracy of scientific methods. If he still survives this, a few weeks later try him on the "Determination of the Concentration of a Solution by Titration," as the colored gentleman says, "paregorically speakin'," and you will be lucky if the turtle now beheaded still retains sufficient vitality to wiggle his tail.

I have before me a copy of the School Review for October, 1897, containing an article prepared by the Department of Chemistry at the University of Chicago, from which I quote verbatim: "Attention should be given to symbols and nomenclature (with careful avoidance of stress, since these are non-essential)." I emphatically disagree with this, and also say that most texts fail miserably here. If you do not understand valence you cannot write formulas. Without nomenclature you cannot interpret them. Without formulas you cannot write equations, and therefore cannot predict what might reasonably be expected to happen in a given reaction, nor can you account for what is taking place before your eyes. Neither can you reason how to prepare certain materials, if wanted; nor can you so easily remember how things are made. Without your equations you cannot solve problems, for your data for the problems come from the equations. I know that a knowledge of these things is appreciated by high school students. In fact, there is a point at which they demand to know these things. They can easily be taught to the average high school pupil, and these steps of instruction follow as logically as night follows day. The class will take on new life and feel that it has a real grasp on the situation. We drop laboratory work and spend all recitations and laboratory periods for three weeks, at about Christmas time, on the development of these fundamentals, and no one is given credit for the first semester's work until he can pass a satisfactory test on them.

One text devotes but one paragraph to ionization, hydrolysis, chemical equilibrium, and mass action, and says that these are interesting subjects but too difficult for the high school pupil. Several others include from eighteen to thirty pages on these topics. There is evidently a lack of agreement in these two extremes. There is a tendency to overdo these subjcts at the present time.

Times and conditions change. A few years ago we were warned not to attempt to teach the pupils anything about the structure of the atom. Well, we didn't know much ourselves at that time, but papers and magazines have mentioned these so frequently, that the pupil's curiosity on these things must

be satisfied. It is difficult, but hardly more intricate than radio, and many boys of twelve or fourteen in five minutes can floor the average high school teacher of physics with questions on radio. I had studied physics under the world-famous Dr. Millikan, and had taught high school physics seven years. My young son was entering high school. I did not pretend he could tell me anything. He came home with $2.00 worth of junk he had picked up from the boys, began to string the house with wire, and in a few weeks the chandeliers were spitting fire and I almost had nervous prostration for fear the house would burn down. He also irritated me very much by talking about such things as grid leaks, amplifiers, cat whiskers, vacuum tubes, variocouplers, etc., and asking me questions that were very embarassing. Here he was, a sophomore in high school who had never studied physics, using a language entirely new to me who had all these advantages. It wasn't long before he had, without any outside help, completed an eight-bulb superheterodyne set. And he says, "Dad, what do you want to hear?" I said, "Give me Los Angeles," and he tunes it in. Dallas, Davenport, Cuba, New York City, Washington, and everyone in the United States is charted and at my beck and call through the boy's dabbling in things I thought he could not understand.

But I did not come here to complain, or to render an indictment against present-day chemistry teaching, but to bring you something constructive—to help build up, rather than to tear down. What can I suggest that will help to put new life into old chemistry?

I have just tried to show you what an average boy can do, if he is really interested in his work. It's an old saying that "You can lead a horse to water, but you can't make him drink." But you can give him salt and make him want to drink. Interest is the salt that creates a thirst for knowledge and a desire for work. Davy, Faraday, Newton, Watt, Galileo, Darwin, Huxley, Edison and Pasteur, all of them had it. One of my favorite teachers put it this way: "God never inspired a lazy man." Show me the man not interested in his work, and I will show you a failure.

Know your pupil. The first day have him fill out a blank, giving his name, age, class rank, whether or not he has studied physics, why he is studying chemistry, what college or univer-

sity he expects to attend, if any. File these where you can get your finger on them at a minute's notice. They are a great help to making personal contact with the individual.

Introduce the pupil to the proper atmosphere for chemistry study the first day. Confront him with quotations on the wall, permanently placed and emphasizing the value of all knowledge and the joy of labor, as: "It is your privilege to know," "Finding out is fun and work is living." These are silent sermons and will often stay with him for life. I find them written in their texts. Pupils meet me in after years and say, "I never shall forget some of the mottoes on your wall." Place permanent display cards on the walls of your recitation room and laboratory emphasizing the practical uses of chemistry. Following are some of those I use: "A knowledge of chemistry is an aid to good health." "By applying chemistry, Rockefeller saw millions in crude petroleum oil." "The chemist has run the food faker to earth." "Baking powder, the leaven of civilization, is a product of chemistry." "Millions of dollars are saved annually because the chemist gave us the fire extinguisher." "A match is a little thing, but a very convenient one." "Pure graulated sugar is the chemist's greatest contribution to the world's dietary." "Chemistry has placed the royal purple of the ancients on the bargain counter." "The chemist has embalmed the voice of Caruso and Galli Curci in carbolic acid." When Dr. Slosson visited us he said he thought it was a fine idea.

Have photographs of the eminent chemists on the wall, to which frequent references are made: Priestly, Lavoisier, Boyle, Dalton, Faraday, and others; and when studying their work, associate the man with his labor. Make them your personal and intimate friends. All of us are inspired by association with the masters. As their teacher, you yourself must be interested in your work. Interest is contagious.

Compel their confidence in you from the first, as a man and as a scholar. You cannot lead those who have no confidence in you. Be neat, be firm, be fair, be honest, be honorable, and have a sense of humor in awkward situations. First impressions are often lasting.

Take advantage of every day's lesson, and drive it home with applications to every-day life, to the home, to commerce, to industry. This is live chemistry. "Live chemistry must mean chemistry learned so that the pupil is interested in it and becomes more intelligent during the process. It must be chemistry, or it is not what we are discussing. It must be alive, or it is not education. It therefore must be both." Contact the work with the pupil's present knowledge, advancing progressively from the known to the unknown. "Put the hay down where the horse can get it." Being accustomed to the language of chemistry, we forget that although this is English, it is in a sense a new language to the pupil. You congratulate yourself that you see through things quickly, but you are not thinking them through,—you already know them. Shift to zoology, with which you are not so familiar, and see the difference. If I state the proposition thus: "If there are more cows in the world than there are hairs in any cow's tail, then there must be at least two cows with the same number of hairs in their tails,"—you cannot remember just what I said, to say nothing of seeing through it. But if I say: "If there are more atoms in the world than there are different atomic weights, then there must be at least two atoms with the same atomic weight,"—you see it, and think you thought through it; but you already knew it. Now, as a good teacher, you start in on the cow problem thus: "Suppose there are just four cows in the world, and that is more cows than there are hairs in any cow's tail, then one cow could have one hair, the second two hairs, and the third three hairs. Obviously, the fourth cow must have either one, two or three hairs in her tail, and at least two cows would have the same number of hairs in their tails."

Give the pupil only what he can assimilate with a reasonable effort. To complete the text is by no means a necessity. A clear understanding of valence, nomenclature, formulas, and equations is essential. Impress the fact that chemistry is as definite as mathematics. There is no half-way ground. A conclusion is either right or wrong. In chemical changes every atom is accounted for. A study of atomic structures makes research work more definite. Material for which you can show no good reason should be omitted. Adapt the work to your community. There is a local chemistry which no text can give, which few teachers know, and fewer teachers teach.

The following are emergency methods one can use, if necessary, to interest his community in chemistry:

Lectures to pupils on "Some Interesting Chemical Experiments," "Soda Water," "The Air We Breathe," "The Water We Drink," "The Food We Eat," "The Clothes We Wear."

A series of practical experiments on "Tests for Food Constituents," "Water Analysis," "Milk Analysis," "Tests for Adulterants in Foods," "Soap Making," "Testing Cloth Fibers," followed by a written report on investigations made at home on foods, textiles and labels on canned goods, in place of the regular monthly test.

A board of food inspectors, who purchase foods in the local market and test them under my supervision and hand me written certified reports of their findings.

Lectures before boys' clubs, men's clubs, and women's clubs, on timely topics, as: "Adulterants in Foods," "Science and Warfare," "The Relation of Chemistry to the Home, to Health and Disease, or to the Enrichment of Life." Articles in the local papers on "Our Local Food and Milk Supply."

Have a bulletin board on which are pasted photographs of noted living scientists, articles taken from magazines and newspapers, jokes, cartoons, about everything pertaining to chemistry or the value of an education. This is not only chemistry up-to-date, but up-to-the-minute.

Require each pupil to read Dr. Slosson's "Creative Chemistry" before the end of the first semester. Probably no book of any time has done so much to interest the masses in chemistry. Here is a man who knows what he is talking about, and also knows how to tell it,—a rare combination indeed. One pupil said: "Mr. Osborne, father is reading it. May I please keep it a little longer?" "Another said: "You required me to read it, but I thank you for it."

Compete in the prize essay contest conducted by the American Chemical Society. It can do no harm, and will be of great benefit to those who take part in it. During the second semester read the "Life of Pasteur," by Radot, as an illustration of the method and work of the world's greatest scientist, or write an essay of at least two thousand words on some subject in which the pupil is interested.

Use project work. In every project, on a small scale, the pupil is duplicating the method of the master in solving his problem. Life's problems are solved in exactly the same way. This is best emphasized in the Chemistry exhibit, or open house. It is not a chemistry show, but about the most serious piece of work the teacher has undertaken. The following points about the open house should be emphasized:

1. More than five hundred persons came to the exhibit, where not more than four or five visit the regular recitation and laboratory work during the year.
2. It is interesting to the teacher as well as the pupil, and I learn more from it than the pupil.
3. It gives a number of boys and girls an opportunity to show their ability, who do not ordinarily take part in public affairs or in athletics.
4. It acquaints the community with the splendid equipment and facilities of the chemistry department.
5. It impresses the public with the practical value of chemistry.
6. The pupils take pride and pleasure in doing and explaining these things, and a new and practical interest in chemistry is awakened.
7. Parents and teachers meet under most favorable conditions.
8. It increases the enrollment materially.
9. The best things that have ever been said in the public press about me and my work, have been said by those who visit this exhibit. The value of such unsolicited praise in its influence on the community is immeasurable.

Good laboratory equipment, kept in good repair, neat and orderly arrangement of bottles and experiments, abundance of supplies with which to work, prompt correction of note books, are aids to maintaining the interest after you get it.

Remember that there are three parts to the recitation: examination, instruction and drill. Examination to find out whether the pupil has done his duty and prepared the task assigned, and also to find out whether he understands it. Instruction to help him see clearly what he does not understand, and also to tell him something he does not know. Drill, for only by

repeating facts and reviewing principles can we drive them home and make them stick.

Know definitely what you are trying to do, and work definitely toward that goal. Through the recitation I expete to give the pupil a working knowledge and understanding of chemistry, and through the laboratory I expect to develop sufficient self-confidence so that the pupil can turn to an experiment, read it, get his supplies, construct the apparatus, make the experiment, see and understand what is going on, and write up an intelligent, logical report on it, and hand it to me.

To put new life into old chemistry, you must not only know chemistry and love to teach chemistry, but you must also live your chemistry. The pupil will catch your enthusiasm and will realize that it is a privilege to know; that it is a wonderful world in which he lives; that the world was not built by chance. He will understand the world better and will, therefore, be the better fitted to live in it. His mind will be on things worth while, and to him finding out will be fun and work will be living.

A Ninth Grade Course in General Science.

WINIFRED PERRY and KATHARINE OWERS,
Roosevelt Junior High School, San Diego, California.

AIMS.

The aims in a ninth grade general science course are:

1. To enable the pupil to adjust himself to his environment.
2. To interest pupils in science.
3. To give pupils a general scientific background, which will enable them to read intelligently.
4. To give pupils practice in logical thinking.
5. To develop open-mindedness, which is the foundation of thoughtful citizenship.
6. To serve as an introduction to specific sciences.
7. To develop powers of accurate observation.
8. To improve health standards.
9. To enable pupil to control and improve his immediate physical environment.
10. To develop a spirit of world interdependency.

I. THE AIR.
  A. A physical mixture of gases.
  B. Properties of the air.
    1. Transparent.
    2. Odorless.
    3. Colorless.
    4. Composition.
      a. Oxygen.
        1′. Preparation and reaction.
        2′. Properties.
        3′. Oxidation and combustion.
        4′. Place in the world.
        5′. Reference—"Oxygen at Work and Play, in "Nature Secrets."
      b. Water Vapor.
        1′. Hydrogen.
          a′. Preparation and reaction.
          b′. Properties (compare with helium).
          c′. Uses.
          d′. References.
            1″. Helium, the new Balloon Gas. (National Geog, Mag., May '19)
            2″. Seeing America from Shenandoah. (Natl. Geog. Mag., Jan. '25)
        2′. Electrolysis of water—demonstration.
          a′. Electrolytes.
          b′. Dry cell—arranged in series.
        3′. Atoms, molecules, elements, compounds.
          a′. Symbols.
          b′. Atomic weights.
          c′. Simple reactions.
          d′. Solar systems inside the atom. (Sci. Amer. 2/25)
        4′. Evaporation.
          a′. Experiment No. 30.
            Lab. Problems—Caldwell, Eikenberry & Glenn.
            1″. Temperature.
            2″. Laws of evaporation. Barber, page 11, Problems and Comparison of Thermometer Scales.

3″. Experiment 10, Lab. Problems.

5′. Humidity.

a′. Absolute and relative.

b′. Use of hygrometer.

c′. Humidity related to health.

d′. Reference—Predicting Forest Fires. (Sci. Amer., Feb. 1925)

c. Nitrogen.

1′. Preparation.

2′. Properties.

(Nature Secrets—"Lazy Boy Nitrogen")

(Creative Chemistry)

3′. Importance.

d. Carbon dioxide.

1′. Preparation.

2′. Sources.

3′. Uses.

a′. Fire extinguishers.

b′. Cooking.

c′. By plants.

1″. Photosynthesis.

a″. Cells.

b″. Osmosis.

(1) Solutions.

(2) Specific gravity.

(3) Metric system of volume and weight.

d′. Respiration—lungs and respiratory tract. Reference—Film, "The Flame of Life."

5. Air fills space.

a. Demonstrations.

6. Does air have weight?

a. Demonstrations.

7. Is air matter?

a. It has weight, fills space, and is therefore a substance.

1′. Class exercise. Find the weight of air in the room, using metric system of length and weight.

b. It expands and contracts with heat. Demonstration.

8. Can air be compressed?
   a. Demonstrations.
   b. Uses of compressed air.
   c. Class discussion.
      1′. Pumps, doors, diving-bells, air-brakes.
9. Does air have pressure?
   a. In all directions. Demonstrations.
   b. Barometer.
      1′. Torricelli's Tube.
      2′. Aneroid barometer.
      3′. Mercurial barometer.
   c. Air pressure at different altitudes.
      1′. Effect upon boiling point.
10. Winds, or air in motion.
   a. Caused by unequal pressure due to unequal temperatures.
   b. Highs and lows.
      1′. Class exercise in using weather maps.
   c. Cyclones and tornadoes.
      (Nature Magazine, March, 1924)
      (Literary Digest, April 5, 1924)
11. The weather.
   a. Factors of:
      1′. Winds, convection currents.
      2′. Pressure.
      3′. Temperature.
      4′. Latitude and longitude.
      5′. Precipitation.
         a′. How clouds are formed.
            Exp. Bowden, Chap. X.
            1″. Kinds.
         b′. How frost and dew are formed.
            Exp. Bowden, Chap. X.
         c′. How rain, snow and hail are formed.
            Exp. Bowden, Chap. X.
         d′. References:
            1″. Explorations in Cloudland—Nature Mag., Feb. 1925.
            2″. Snow Time in Nature Land. Jan. 1924.

3″. Magic Beauty of Snow and Dew—Natl. Geog. 1/23.

b. Weather instruments and their uses.
1′. Thermometers.
2′. Barometers.
3′. Hygrometers.
4′. Anemometers.
5′. Rain gauge.

c. Value of the weather service.

d. Climate, the total of weather conditions.
1′. Climate of San Diego.

e. The seasons and their causes.
(Film—"The Seasons")

f. References:
1′. "Curious ways in which the weather affects business." (Amer. Mag., Aug. 1922.)
2′. "Speaking of the weather."—U. S. Year Book of Agriculture, 1920.
3′. "The Boy with the U. S. Weather Man."—Wheeler.
4′. "Some Useful Weather Proverbs."—U. S. Year Book of August, 1912.
5′. "Lightning." (Amer. Mag., July, 1922.)

g. Class exercise.
1′. Keep weather records for one month and make graphs of temperature, humidity and pressure.

II. CLOTHING.

A. Fibers used for clothing and their sources.
1. Wool (Nature Magazine, Feb. 1924).
2. Silk (Life History of Silkworm—Metamorphosis).
3. Cotton (Nature Magazine, Mar. 1924).
4. Flax.

B. Purpose of Clothing.
1. To maintain body temperature.
a. Conduction and radiation of heat.
1′. In all substances. Experiment.
2′. In materials used for clothing. Experiment.

C. Tests to distinguish various fibers.

1. Microscopic.
2. Chemical.
   a. Characteristic of acids.
   b. Characteristic of bases.
   c. Reaction of acid and base—Salt and H_2O (Neutralization).
      1′. Laundry.
         a′. Hard and soft water.
         b′. Soaps.
      2′. Dry cleaning.
         a′. Solvents and fats.
         b′. Removal of paint stains.
   d. Dyeing and mordants.
      (Chemistry of Common Things, Chap. 29)
      (Hodgdon, General Science)

III. WATER.

A. Importance of water.

B. Three forms of water.
   1. What happens when water boils? Exp. 29. Laboratory Problems.
   2. What happens when water freezes? Exp. 28. Laboratory Problems.
   3. Distillation and condensation.
      a. Review dew-point.
   4. Electrolysis of water. (Review)
   5. Why does ice float?
      a. Experiments to illustrate Archimedes' principle.
      b. Specific gravity of substances.

C. Pure water.
   1. San Diego's water supply.
      a. Excursion to filtration plant—Otay.
      b. Water-sheds contributing to our water supply.
   2. Dangers to a water system.
      a. Faulty sewers.
      b. Careless campers.
      c. Poor sanitation in general.
      d. Algae in reservoirs.
         1′. Study of spirogyra.
      e. One-celled organisms. (Review)
   3. A water-borne epidemic of typhoid.

a. What are bacteria? Louis Pasteur, Lester, Jenner, Koch.
b. Conditions necessary for growth.
1′. Food and moisture.
a′. Preparation of solid and liquid media.
2′. Temperature.
a′. Minimum.
b′. Maximum.
c′. Optimum.
3′. Sterilization.
a′. Of glassware.
b′. Of media.
4′. Other means of communication of typhoid.
a′. Milk.
b′. Human carriers.
c′. Oysters.
4. Other bacterial diseases—tuberculosis, pneumonia, whooping cough, etc. Their control.
5. Diseases due to filterable virus—smallpox, chickenpox, rabies, measles. Methods of control.
6. Protozoan diseases—malaria, etc. Control.
a. Life history of mosquito.
7. Immunity.
8. Work of Public Health Department. See "Healthy Living," Vol. II.
9. Experiment: broth cultures and plates of tap, pond and distilled water, and Exp. 27, Lab. Problems.
10. Experiment to show comparative values of disinfectants, real and so-called.

D. The effects of the action of water upon earth's surface.
1. Running water—erosion.
2. Glacial action.

IV. EARTH.

A. Three-fourths of earth's surface covered by water.
1. In forms of:
a. Oceans (Density of salt and fresh water). "The Ocean."
b. Lakes.
c. Rivers.

d. Flood plains.

B. Physiography of California and San Diego County.

C. Earth's place in Solar System.—Newton, Gravity, Centrifugal force.

1. Planets.
2. Suns (Stars).
   a. Ether waves. Exp. to show how light and sound travel.
3. Moons.
   a. Tides.
4. Nebulae.
5. Meteors.
7. Eclipses of sun and moon.
8. Astronomical instruments.
   a. Telescope—Herschel, Galileo.
   b. Spectroscope.
      1′. Experiments with prism and color wheel.
9. References:
   a. The Wonders of the Earth's Front Yard.
      American Magazine, Aug. 1922.
   b. The Sun and His Family.
      American Boy, April, 1922.
   c. The Monthly Evening Sky Map.
   d. The Moon Our Nearest Neighbor.
      Nature Magazine, Feb. 1924.

D. Composition of the earth.

1. Bed rock and mantle rock.
2. Rocks, minerals and soils.
   (Fairbanks' Minerals of California)
   a. Kind of rocks with chemical composition.
      1′. Metamorphic.
      2′. Igneous.
      3′. Sedimentary.
   b. Minerals of California and San Diego County.
      1′. Special reports.
      2′. Students' collections.
   c. Soils.
      1′. Five parts of a soil.
         a′. Rock portion.

1″. Weathering agents.
b′. Humus.
c′. Water.
1″. Irrigation.
2″. Dry farming.
3″. Drainage problems.
d′. Air.
1″. Tillage.
e′. Organisms.
1″. Bacteria.
2″. Earth-worms.
3″. Insect forms.
2′. Soils as to origin.
a′. Sedentary.
1″. Residual.
2″. Cumulose.
b′. Transported.
1″. Glacial.
2″. Aeolian.
3″. Alluvial.
4″. Colluvial.
3′. Fertility of soil.
a′. Essential elements of plant foood.
1″. Experiment: Pfeffer's solution and water cultures.
b′. Fertilizers.
1″. Barn-yard manures.
2″. Commercial fertilizers.
a″. Nitrogenous.
b″. Phosphatic.
c″. Potassium.
d″. Complete fertilizer.
3″. Experiment to test comparative values of different fertilizers.
4″. Nitrogen cycle.—Hunter's Civic Biology.
5″. Carbon-oxygen cycle—Hunter's Civic Biology.

E. Plants that live on earth.

1. Exercise to determine pupils' knowledge of the

plant as a whole. Study of a plant as a whole. Draw a plant, naming all the parts. On the back of paper tell as many functions or uses of each part or organ as possible.

2. Detailed study of a seed plant.
   a. Leaves.
      1′. Draw a leaf to locate blade, margin, petiole and mid-rib.
      2′. Functions.
         a′. Photosynthesis. (Review)
         b′. Transpiration.
            (Review evaporation.)
            1″. Experiments.
            2″. Reference—"How the Forests Feed the Clouds," in Science Remaking World.
         c′. Respiration.
            1″. Experiment with elodea or spirogyra.
   b. Roots.
      1′. Draw roots to illustrate the following terms: primary, secondary, tap, fibrous.
      2′. Functions.
         a′. Anchorage.
         b′. Absorption. (Review osmosis.)
         c′. Storage.
      3′. Roots that are used for food.
   c. Stems.
      1′. Types.
         a′. Erect.
         b′. Horizontal.
         c′. Underground—bulb, tuber, rhizome, etc.
      2′. Functions.
         a′. To connect roots and leaves.
         b′. To bear leaves and flowers.
         c′. Photosynthesis.
      3′. Stems used for food.
   d. Flowers.
      1′. Study of a perfect flower.
         a′. Draw a flower of single geranium, naming calyx, corolla, stamens, pistil.

b′. Make an enlarged drawing of a stamen, naming anther and filament.
c′. Make an enlarged drawing of a pistil, naming stigma, style, ovary.
d′. Examine some pollen under h. p. microscope.
e′. Germinate pollen in 3% and 5% sugar solutions and examine.

2′. Purpose of flowers—to produce seed.
a′. Pollination and fertilization.
b′. Hybrids and Mendel's law—"The Next Generation." Entire book.
c′. Plant breeding.
Luther Burbank, "New Creation in Plant Life."

e. Seeds.
1′. Study of bean and corn as examples of dicotyledons and monocotyledons.
a′. Draw seeds and germinating seeds.
2′. Factors necessary for germination.
3′. Chemical changes in seeds during germination.
4′. Tropisms; geotropism, phototropism.

f. Means of reproduction other than seeds:
1′. Tuber, corm, runner, layering, budding, grafting, bulb, rhizome, spore, cutting.

g. Plants and landscape gardening.
1′. Fundamentals of:
a′. Open spaces.
b′. Curved lines.
c′. Plant in masses.

h. Non-flowering plants.
1′. Fleshy fungi.
2′. Algae.
3′. Rusts and smuts.
4′. Yeasts and molds.

i. Reference:
1′. "Exploring the Mysteries of Plant Life." Nat. Geog., June, 1924.
2′. Film—"How Life Begins."

3′. "How Human Traits are Inherited." World's Work, Jan. 1925.

F. A rapid survey of animal kingdom.
1. Set of 100 slides, "From Amoeba to Man."
3. Excursions to Science of Man Building.

G. Man as a machine—Metabolism.
1. Digestion.
a. Foods.
1′. Classification of foods.
a′. Carbohydrates.
1″. Composition.
2″. Tests for sugar and starch.
3″. How used by body.
4″. Reference—"The Story of Insulin, World's Work, Nov. 1923.
b′. Protein.
1″. Composition.
2″. Tests for.
3″. How used by body.
c′. Fats.
1″. Composition.
2″. Tests.
3″. How used by body.
d′. Minerals.
1″. Uses.
e′. Water.
f′. Vitamines A—B—C—D—X.
1″. Where found.
2″. Effect upon body.
g′. Ash.
2. Available foods.
a. Due to geographical location.
b. Rural and city food supply.
3. The purpose of food.
a. Fuel.
1′. Calories and the calorimeter.
b. Growth and repair (Maintenance).
4. Well balanced meals, economically planned, at regular times.
a. Class exercise to plan menus for one day for H. S. child.

Reference: "Please Pass the Iodine." Woods Hutchinson, Sat. Even. Post, Jan. 3, 1925.

b. Preparation of food for digestion.
c. The digestive tract.
1′. The Mouth.
a′. The teeth—mastication.
b′. Saliva—ptyalin.
2′. Oesophagus.
2′. Stomach.
a′. Gastric juice.
1″. HCl.
2″. Rennin.
3″. Pepsin.
4′. Small intestine—peristaltic action.
a′. Alkaline secretions.
1″. Pancreatic juice.
a‴. Trypsin.
b‴. Steapsin.
c‴. Amyopsin.
2″. Bile.
a‴. Saponification.
b‴. Inhibiting effect upon bacteria.
c‴. Helps in absorption of fats.
3″. Intestinal juice.
a‴. Digestion of fats.
b′. Absorption.
1″. Villi.
a‴. Capillaries, lacteals. (Review osmosis.)
5′. Large intestine.
a′. Some absorption.
b′. Mucin—a lubricator.
c′. Elimination of waste.

2. Circulation.
a. The heart—Cardiac muscle.
1′. Divisions.
a′. Auricles.
b′. Ventricles.
2′. Coronary artery and vein.

b. Arteries, veins, capillaries.
c. The blood.
1′. Composition.
2′. Amount.
3′. Types for transfusion.
d. The circulation of the blood.
3. Respiration.
a. Respiratory tract and purpose of parts.
b. Lungs—structure.
c. Relation of lungs to circulation.
d. Diseases of respiratory tract. Review.
4. Excretion.
a. Lungs.
b. Kidneys.
d. Liver.
e. Intestines.
5. Skeleton.
a. Purpose.
6. Muscles.
7. Communication system of body.
a. Central nervous system.
1′. Brain and spinal cord.
b. Sympathetic nervous system.
c. Habits and reflex action.
d. Effects of narcotics and stimulants on nervous system.
8. Special senses.
a. The eye.
1′. Structure.
2′. The eye and light.
a′. Composition of light (spectroscope).
b′. Speed of light.
c′. Opaque, transparent, translucent.
d′. Reflection and refraction.
e′. Mirrors and lenses.
b. The ear.
1′. Structure.
2′. The ear and sound.
a′. Nature of sound.
b′. How sound travels.

c. The nose.
1′. Structure. (Review)
d. The tongue.
1′. "Geography" of tongue.
e. The skin and touch.
1′. Structure. (Review)

9. What man has done with his brain.
a. Man's early achievements.
1′. Fire building.
2′. Weapons.
3′. Home building.
4′. Reference: "Story of Mankind."
b. Means of transportation.
1′. By land.
a′. Feet—physiology and care of.
b′. Beasts of burden.
c′. Simple machines.
1″. Lever.
2″. Wheel and axle.
4″. Inclined plane.
5″. Screw.
6″. Wedge.
d′. Steam engine—James Watt.
1″. Principle.
e′. Gas engine.
f′. Electrcity.
1″. Magnets.
a″. Their properties.
b″. Types.
(1) Temporary—Door bell—Experiment.
(2) Permanent.
c″. Magnetic fields of force.
d″. Laws of magnetic poles.
e″. Compass and its use.
f″. Experiments:
(1) To magnetize an iron bar in field of another magnet and in earth's magnetic field.

(2) Compass near a wire carrying electric current; reverse flow.

2″. Sources of electricity.
  a″. What electricity is.
    (1) Electron theory.
  b″. Methods of producing electricity.
    (1) Frictional or static.
    (2) Chemically, such as gravity cell.
    (3) Electricity from dynamos.

3″. Electric current.
  a″. How produced.
  b″. Kinds: A. C. and D. C.
  c″. Methods of conducting.
    (1) Insulators and conductors.

4″. Units used in measuring electricity.
  a″. Ohm.
  b″. Watt.
  c″. Volt.
  d″. Ampere.

5″. Instruments used in above measurements.
  a″. Voltmeter—practical uses of.
  b″. Ammeter—practical uses of.
  c″. Watt-Hour-meter — practical uses of.
  d″. Galvanometer—practical uses of.

6″. Chemical effects of electric currents.
  a″. Electro-plating.
    (1) Copper, silver, gold, etc.
  b″. Automobile storage battery.
    (1) Its use and proper care.
      (a) How tested with hydrometer.

7″. Electric motor.
  a″. Principle of a motor and how it works.
  b″. Different kinds of motors.

c″. Domestic and commercial uses of motors.

2′. By water.
a′. Rowing (review lever).
b′. Sailing.
c′. Steamboat (Robert Fulton).
d′. Gas engines.
e′. Sub-marine.
1″. Cartesian diver.
f′. Hydroplane.
3′. By air.
a′. Lighter-than-air craft.
1″. Balloon and dirigible.
b′. Heavier-than-air craft.
1″. Airplane.
a‴. References:
"Man's Progress in Conquering the Air."—Natl. Geog., July, 1924.
"The Non-Stop Flight Across America."—Natl. Geog., Jul, 1924.

c. Means of communication.
1′. Primitive means.
a′. Early writing.
b′. Signal fires.
c′. Heliograph.
d′. Runners.
2. Modern means.
a′. Mail.
b′. Printing.
c′. Telegraph.
1″. Parts and uses of Morse instrument.
2″. The Morse code.
3″. American telegraph system today.
d′. The telephone.
1″. Bell's early experiments.
2″. Parts of instrument and system circuits.
3″. The automatic telephone.

4″. Reference, "Alexander Graham Bell," in Nat. Geog. Mag., Sept. 1922.

e′. Wireless communication.

1″. Electromagnetic waves.

a″. Speed, character, length, frequency.

b″. Production of electric-magnetic waves.

c″. Nature of radio waves.

d″. Apparatus required to produce radio waves.

(1) Radio frequency generator.

(2) Modulator.

(3) Radiator or antennae system.

(a) Transformers and their use in radio.

e″. Receiving equipment.

(1) Antennae or aerial to intercept the elctro-magnetic waves.

(2) Coils.

(3) Condensers.

(4) "Detector."

(5) Telephone receivers.

10. Man's place in the animal kingdom.

a. Developmental ideas—protozoa to man.

b. Evidences of evolution.

1′. Fossils.

2′. Geology.

3′. Embryology.

4′. Comparative anatomy.

5′. Ethnology.

SUPPLEMENTARY REFERENCE BOOKS

1. Elements of General Science—Laboratory Problems—Caldwell, Eikenberry, Glenn—Ginn & Co.
2. Nature Secrets—Mary E. Chambers—Atlantic Monthly.
3. Creative Chemistry—Slosson—Century Co.
4. The Boy with U. S. Weather Man—Wheeler.

5. Science of Plant Life—Transeau—World Book Co.
6. Minerals of California—Fairbanks.
7. Chemistry of Common Things—Brownlee, Fuller, Hancock, Whitsitt—Allyn & Bacon.
8. Practical Physics—Carhart & Chute—Allyn & Bacon.
9. Practical Electricity for Beginners—Willoughby—Manual Arts Press, Peoria, etc.
10. Science Remaking the World—Caldwell & Slosson—Doubleday Page.
11. Science of Common Things—Tower & Lunt—D. C. Heath.
12. Outlines of Anthropology—Merritt.
13. Letters from a Radio Engineer to his Son—Mills.
14. The Boys' Playbook of Chemistry—Gates—The Century Co.
15. How to Live—Fisher and Fiske—Funk, Wagnalls Co.
16. Discovery—The Spirit and Service of Science—Gregory—Macmillan.
17. The Ocean—Sir John Murray.
18. Civic Biology—Hunter—American Book Co.
19. Healthy Living—Winslow—Merrill.
20. New Creations in Plant Life—Harwood—Macmillan.

MAGAZINES.

Scientific American
Nature Magazine
Popular Science Monthly
Science News Letter
Hygeia—American Medical Assn.
Science and Invention.
Monthly Evening Sky Map.

TEXTS.

Bowden—General Science—Blakiston.
Barber—General Science—Henry Holt & Co.
Caldwell & Eikenberry—General Science (Revised Edition)—Ginn & Co.
Snyder—Everyday Science with Projects—Allyn & Bacon.
Hessler—The First Year of Science—Sanborn.
Jewett—The Next Generation—Ginn & Co.

Science Teaching a Third of a Century Ago.

THE STUDY OF NATURAL SCIENCE—ITS USES AND DANGERS.[1]

WILLIAM T. HARRIS.

NATURAL science, the investigation of nature, is well said to be the characteristic intellectual activity of modern civilization. An acquaintance with the several provinces of nature and their relations to each other has brought with it an era of invention of labor-saving machines. With machinery man has been to some extent emancipated from drudgery, and the work of this emancipation is going on at an unceasingly rapid rate. There is less hand labor and more labor of directive power. Man uses higher powers to direct a machine to do his

1 Extracts from address delivered at a meeting of the American Institute of Instruction at Bethlehem, N. H., July 9, 1889.

work than to perform the same work by hand; and the machine increases his production to such a vast extent that with fewer hours of labor he obtains far more.

By machinery man turns nature against herself; for it is nature in our bodies that makes us want food, clothing, and shelter. Nature furnishes the supply for those wants, but at a great cost of bodily labor. At first, man is bound to nature as her serf, his physical wants obliging him to toil for their gratification. By learning the materials in nature's storehouses, and the laws of natural forces, man becomes able to harness those forces and set them to work elaborating supplies of food, clothing, and shelter, collecting them into the world market, and distributing them to all mankind represented in that market. Thus nature is made to provide for its own wants—takes care of itself, as it were—and man is left more and more independent to care for the needs of his immortal soul.

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Natural science indeed has stimulated inventions of most marvelous means of preserving and disseminating the wisdom of the race. The arts of writing and printing, added to such devices of intercommunication as the telegraph and railroad, have produced the modern daily newspaper, which reflects as a magic mirror the entire world of man's doings, good and bad. Not only may man read as he runs, but knowledge runs after him, and the world holds up her picture to him at every turn.

While a continuously large proportion of the entire civilized world, from year to year enjoy more comfortable houses, more substantial clothing, more abundant and more wholesome food, their progress in these material aspects is not really so rapid as in the spiritual phase of participation in the wisdom of the race through the arts of intercommunication.

Natural science, knowledge of nature, has been the chief instrument in all this progress. What are its methods? There are three stages in the development of science. First, there is the observation of things and facts: the scientist must map out and inventory the objects in each department of nature; secondly, the interrelations are investigated, and this leads to a knowledge of forces and influences which produce or modify

those objects which have been inventoried in the first stages of science. This is a dynamic stage, the discovery of forces and laws connecting each fact with all other facts, and each province of nature with all other provinces of nature. The goal of this second stage of science is to make each fact in nature throw light on all the other facts, and thus to illuminate each by all. Out of this there arises the system of the whole, and the third stage of science is reached. Science in its third and final stage learns to know everything in nature as a part of a process which it studies in the history of its development. When it comes to see each thing in the perspection of its evolution, it knows it and comprehends it.

Natural science as a whole is not very old, but it has resulted in an age of invention and productive industry. The third epoch of the development is but begun and only on some lines of investigation. Is there any question that so great an instruction of human progress should have a prominent place in school instruction?

In order to look at this subject in some of its details, let us consider first the grand division under which it falls.

Nature is in time and space, and these furnish, so to speak, the logical conditions of existence for all its objects and all their processes. Matter and movement include space and time. Inasmuch as the human mind knows space and time are *a priori,* and can think out their laws without first having to collect examples and generalize from facts, it has invented the science of mathematics, the most wonderful of the tools of thought in the investigation of nature. Mathematics tells us what must be, not what merely has been, so far as we have experience of it. By its aid man assumes a commanding attitude toward nature. He can announce laws of existence and action which nature must obey. The three angles of a plane triangle are equal to two right-angles, and it is impossible for nature ever to furnish a plane triangle with a greater or a less sum for its three angles.

Pure mathematics is *a priori* or independent of experiment; it studies what may be called the general form of the possibility of nature. Applied mathematics inventories facts regarding matter and motion and interprets these facts in the light of mathematics. This forms the science of physics, or "natural

philosophy" as it used to be called. With chemistry, which deals with composition and combination, we have two branches of physics, molar and molecular,—the science of nature as masses and molecules, and movements of the same.

Mathematics and physics treat of nature as inorganic. Even so-called "organic chemistry" treats all bodies as inorganic and reduces them to their inorganic constituents and tells nothing of the organic principles as such.

The first phase of natural science deals with the inorganic. The second deals with organic nature,—plants, animals, and formative processes like meteorology and geology, and cyclical processes like astronomy. This is the total survey of natural science. The method of study of the inorganic is chiefly mathematical and relates to measurement of quantity of nature and quantity of motion, and quantity of force manifested in qualities and movement. The method of study of inorganic nature is historic—an inventory of things and a record of their metamorphoses.

Science study in schools as a matter of instruction involves first the presentation of results, interesting details reached by practical applications or seen in their relations to the general principles ascertained; secondly, instruction involves the method of investigation. The student learns the method of making experiments and of verifying results recorded. He learns how, as a specialist, to make additions to the existing stores of science.

By reason of its importance, the study of natural science should begin early in school, but on account of its methods, which require maturity in the student, as well as because of the fact that the study of nature is only a small portion of human learning, it must not occupy a large place in the programme. It is quite sufficient for common district schools to devote one hour each week to the principles, beginning in the lowest grades of the primary school. This hour should not be divided into fifteen-minute object lessons and scattered throughout the week, but should be one united lesson. In it he should take up in systematic order the important results of science. There should be description, illustration by pictures, models, and natural objects, a conversation with the pupils drawing out what they already have learned on the subject,

and critical comparison made with a view to verify or correct their previous knowledge and thereby teach critical alertness in observation. Pupils should be set to work illustrating and verifying the results presented in their leisure hours doing the work, and lastly, their knowledge should be tested and made exact by short essays written on the contents of the lesson.

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The question that next arises relates to the psychologic value of the study of natural science. For we have justified scientific instruction solely on its significance as a factor in civilization. It is well known that every branch of study in the schools opens some window of the soul. These are grammar, geography and history, arithmetic, and literature: each one gives some new faculty of observation to the mind of the other. What, we ask, does natural science give? First, let us consider the view of the world as a whole that science has furnished, and inquire whether it be a spiritual or a materialistic view. According to the current evolutionary view, all nature is a struggle for survival of forms. Inorganic forms go down before the organic; of the organic forms, the plant serves the animal and yields to him. The animal, in turn, yields to man. Man, in fact, conquers all nature. Here the law of survival of the fittest comes to mean the survival of individuals that have most intelligence.

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True to its categories of quality and quantity, natural science limits itself to observing and recording all relations of the plant to its environment. It carefully measures these, so as to give the accuracy of quantitative statement to its results. It investigates how much heat and how much moisture are required as conditions of growth of the seed. It determines what shall be the character of the soil in which such a seed will germinate. These are the negative conditions.

Without so and so much heat, moisture and sunlight, without such and such kinds of soil, the self-activity of the plant will not manifest itself. Given such and such favorable conditions and the energy of the plant can act and appropriate for itself portions of the surrounding air, moisture, and soil, and after stripping off the forms that they bring with them, the plant stamps them with its own form of vegetable cell and

adds them to its own structure, or grows or increases in size.

Presented in this way, it seems to me that anyone may see already that the plant action is self-activity. The environment may act as much as one likes, but it will not be claimed that the environment brings its material to the plant and then detaches some portion of it which it causes to enter the plant. Still less will it be claimed that the environment acts negatively on itself to destroy its own form and put on the form of vegetable cell of the precise shape, size and composition of the plant which it enters. Each plant stamps its own individuality on its cells, so that if a collection of the cells of one plant be engrafted into another plant, the graft will produce the fruit of the original plant that formed it. So of seeds: an acorn produces an oak or nothing; the seed of a cucumber manifests its self-activity by converting its nutriment into cucumber leaves, vines, and fruit. No change in the environment will produce a cucumber from an acorn, or an oak from a cucumber seed. If a change in the environment, skilfully applied for a long period, develops fine apples from the sour crab apple, we reason that the casual energy is not the plant, which being relieved of the waste of its power upon stubbornly resisting elements of food, has more strength to expend on building up its ideals. To consider the progressive development of a plant due to outside influences, is to suppose that the environment of the approved apple-tree contains the energy that prefers choice fruit to our crabs.

Outside action may be said to assist development, because it may be something to destroy or break down the stubborn individuality of the elements of the environment that serve as food for the living plant, but it cannot be said to assist directly; it cannot furnish organizing power; it cannot build, like the life-power of the plant,—it can only tear down; it can assist only as a mill assists man's life, by grinding his corn for him and saving him so much expenditure of vital force as would be required to grind the corn with his molar teeth.

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In the study of plant life we discover self-activity in the form of assimilation of food from environment. In the case of the animal, we have, in addition to the assimilation processes, new forms of self-activity more remarkable, namely,

feeling and locomotion. In locomotion, self-activity appears as originator of movement in matter; while in feeling, it shows power to reproduce within itself the essential form of its environment. In feeling, the animal becomes its own environment or repeats its environment ideally, and thus manifests a higher capacity than the plant shows.

In man, this self-activity is developed beyond feeling to the perfect forms of thought and will. In these, man frees himself from the meshes of fate; for he does not allow himself to be limited by real being, as it is, but conceives ideal forms of being which he desires. These desires, as motives, he actualizes by his will. In these he is doubly free, doubly a cause,—first, a cause in thinking an ideal as a motive, for a motive is not a real but an ideal form in the mind; secondly, a cause of the actualization of his motive or ideal through his will.

Even the animal shows the action of motives as impulses; the animal as a feeling-being sees ideals to some extent, or else he never would act as he does. The plant is guided by ideals, though it does not feel or think them. In man the ideal exists as an object for itself, for man can see ideals of sense-pleasure, ideals of beauty, and finally, ideals of ethics. In the moral ideal man sees the form of the divine as a necessity elevated entirely above physical necessity—a necessity addressed to the mind as ideal—and hence a form of reedom. The moral is the ideal form of freedom.

Natural science, with its predominant use of the categories of quality and quantity, therefore fails, in the departments of organic nature, to comprehend the plant and animal; and it fails still more signally to recognize the spiritual in man, but the principle of evolution coming to be generally adopted does not encourage this exclusive use of the quality and quantity points of view. Evolution urges on the mind to final causes of purpose and this will be found corrective of the present vicious trend in the method of scientific thought.

While, therefore, we must acknowledge the importance of science study in the elementary schools, we must not ignore its non-spiritual tendency, due to exaggerating the importance of inventorying external facts. Its enthusiasm for things and events in time and space makes it undervalue facts of intro-

spection which are more fundamental than facts of external observation. Self-activity is as truly an object of internal observation as a thing conditioned by its environment is an object of external observation. Moreover, this internal fact of self-activity has to be used in external experience in order to recognize living beings of any sort. Without the concept of self-activity no one would ever come to observe any living beings whatever.

Now, the corrective for such study as lays too much stress on external observation is found ready at hand in the study of human nature. These are philology or language study, history or the study of human will acting to form institutions, and literature as the symbolic presentation of human nature in its entirety. Religious literature, of course, touches the problem directly, and offers to the individual, in the form of authority, the spiritual theory of the universe. But literary art, grammar, and especially history are spiritualizing in their tendencies, and furnish the antidote for the materialistic tendency of scientific instruction in our schools.

Natural Science by the Experimental Method.

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IN the scientific department of the New York College for the Training of Teachers, we are making a careful study of the question whether it is practicable for common schools to give science lessons by experimental methods in every grade from the first year of the primary to the last year of the high school.

We have classes of pupils in all grades in what is called our "Model School," which have a certain portion of their time allotted to the scientific department to be used as the head of that department may see fit. Apprenticed teachers from the college are put in charge of the work, so that the conditions may be as near as possible like those in the public schools.

In the primary and grammar grades, the experiments have been performed by the teachers in the presence of the pupils, and their observations have been elicited by questions. Pupils

1 Extracts from an address given before the American Institute of Instruction at Bethlehem, New Hampshire, July 9, 1899.

have been allowed close examination of the objects, by having them passed around from hand to hand.

It has been our object to train children in the use of their senses and open those avenues through which their minds must acquire a knowledge of nature. We have, therefore, chosen such experiments as would give special training to the senses of seeing, hearing, smelling, tasting and touching. We have made use of the familiar, every-day objects which chanced to be nearest at hand, which cost very little money and very little time and skill for manipulation.

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We have directed the attention of the children to objects of everyday interest, not so much with the idea of loading them with facts as of arousing their curiosity and begetting in them inquiring habits of mind. The custom is very prevalent, where science lessons are given in lower grades, of pouring in facts and requiring the children to memorize certain formulated doctrines of which they can have no adequate conception; and however fundamental they may be as scientific conclusions, the children cannot be considered to be prepared for them.

In the high school department, we begin systematical, scientific instruction for the purpose of developing careful habits of experimenting, careful habits of observing, and careful habits of reasoning. In this department, as in the others, those experiments were selected which would cost the least money and least time for manipulation; which would be the simplest to understand and would most directly illustrate the principles.

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We have taken care that our experiments should be so simple that the pupils might readily understand them, believing that artificial experiments intending to express natural phenomena ought not to be more incomprehensible than the phenomena themselves.

We have made great use of familiar objects which chanced to be nearest at hand for the purpose of demonstration. Our pupils have been taught to construct their own apparatuses so far as there seemed to be additional value in that sort of work; and in most cases, the products of their work unquestionably fulfilled the purpose for which they were constructed much

better than the conventional apparatus, which, expensive and cumbersome, usually have no better mission than to occupy a show-case. Our high school pupils have studied science in the laboratory by the experimental method, working one hour and a half per day, three days in a week, for a whole year, with an average expense of three dollars for each pupil,—which expense the pupils themselves have chiefly borne, in order that they might possess the apparatus which they had made.

The apparatus which is appropriate to be used in most of the experiments for the high school department is that which is sometimes called "illustrative apparatus"; a large part of it should be "home-made apparatus."

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Teaching science by the experimental method prohibits our undertaking to cover as much of the subject as is mapped out in the usual high school curriculum. Nothing could be more impracticable than to undertake to teach by the Baconian method the whole of sociology, physiology, botany, physics, chemistry, astronomy, and geology within the ordinary limits of a high school course. The time allotted to the study of science should not be distributed over such a vast field. The habit of cramming all the facts of a textbook of science should be as loathsome to teachers and school authorities as it is to pupils. It is the business of the school to show the pupil how to study nature, so that through life he may go on to acquire knowledge. To this end, quantity must be sacrificed to quality, and the teacher must not be trammelled by a course of study except in the time allotted. The amount of subject matter which the pupils attempt to grasp must be diminished at least one-half. Too much of the science teaching is beyond comprehension of the pupils. They cannot retain interest long in that which they do not grasp. Not only must the amount of knowledge which is presented to the student be diminished, but it must be greatly simplified. Pedantic essays about nature's laws delivered by youthful graduates are the natural outgrowth of a course of instruction which is as abstruse as it is pharisaical.

It is hard to conceive of a more unscientific method than that which prevails so generally of performing experiments in

a hasty, slipshod way, and attempting to make up for their deficiencies with pedantic explanations.

Careful habits of performing experiments, as well as careful habits of observation and careful habits of reasoning, cannot be cultivated where such haste is required to cover a large amount of subject matter. Our final conclusion is that patience and a love for the work are the most essential qualifications for the teacher. With these and with freedom from unnecessary restraints, however meager other equipments may be, science may readily be taught in the common schools by experimental methods.

Some Properties of the Thermionic Vacuum Tube.

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THE thermionic vacuum tube and the principles underlying its operation are of great interest to the student and teacher of physics. While this remarkable device finds its most important use in radio transmission and reception, it also forms an important link in long distance wire telephony, and its applications in other departments of physics and even in other sciences, such as astronomy and biology, are becoming of increasing importance. It is the purpose of this paper to discuss some of the more important properties of the tube and to show how they may be demonstrated by means of simple experiments suitable for the lecture room and laboratory. No attempt, of course, is made to give anything new, as the construction and the characteristics of various types of tubes have been studied in great detail in recent years, and ample data may be found in standard works dealing with the subject and in the scientific journals.

It is not necessary to state that the thermionic vacuum tube consists essentially of an evacuated glass bulb containing a filament surrounded by a metallic plate, which usually takes the form of a flattened cylinder. Between the two is inserted a fine wire conductor. There are four external terminals, two for the filament, one for the plate, and one for the wire conductor or grid. The size of the tube and the size and form of its elements depend upon the use to which it is to be put. It

is interesting to note that the tube, as we have it, is in great measure an American invention. Its beginnings go back some forty years, when our veteran inventor, Mr. Thomas A. Edison, was developing his incandescent lamp. In the course of his experiments he inserted a metal plate in the bulb near the filament. He found that when this was connected in series with a galvanometer to a terminal of the filament, a current flowed from the filament to the plate when the former was lighted. There was no satisfactory theory at the time to account for the phenomenon, nor did any one dream that it could have any practical application. Mr. Edison, on account of other work, did not continue experiments along these lines. It was shown later that the current was carried across the vacuum by means of electrons emitted by the hot filament. The English physicist, O. W. Richardson, in the early years of the century, made an extensive study of the phenomenon and of the laws connected with it.

According to the ordinary theory, metallic conductors are composed of atoms, each with its requisite number of electrons. A certain number of the latter move with comparative freedom from one atom to another, so that, at any given moment there are a number of free electrons in the metal. The flow of these electrons through the conductor under the action of an impressed electromotive force constitutes an electric current. Atoms and electrons are in a continual state of vibration which becomes more vigorous as the temperature of the conductor is raised. The electrons, on account of their smaller mass, will have the greater velocities and hence will tend to escape from the metal. A surface force akin to surface tension opposes this. A temperature will be finally reached at which some of the electrons will acquire sufficient velocity to escape, very much as molecules escape from an evaporating liquid. According to Morecroft, this velocity, in the case of tungsten, must be at least 10^8 cms. per second. The electrons which escape carry their negative charges with them and leave the conductor positively charged. They are consequently attracted back to it, so that, in the case of a wire conductor heated in a vacuum, a state of equilibrium is finally reached in which as many return as escape. It is important to note that this electron

emission depends not only upon the temperature of the wire, but also upon impurities in the material of which it is made and upon the nature of its surface. The presence of residual gas in the tube also effects the magnitude of the current flowing across the vacuum to a neighboring plate. An experiment, which by the way is mentioned in a recent number of the Zeitschrift für den Physikalischen und Chemischen Unterricht, furnishes some evidence of the presence of these free electrons about a hot wire. A strip of tinfoil is placed about the bulb of an ordinary Mazda lamp and connected with a gold-leaf electroscope. When the lamp is cold, the leaves of the electroscope under favorable conditions remain diverged, whether they are charged positively or negatively. When the lamp is lighted, the leaves, if charged positively, immediately collapse, whereas, if they are changed negatively, they remain unchanged. In the latter case, the free electrons and the negative charge repel each other, and the charge remains upon the leaves. In the former case, the positive charge is attracted by the free electrons and bound by them.

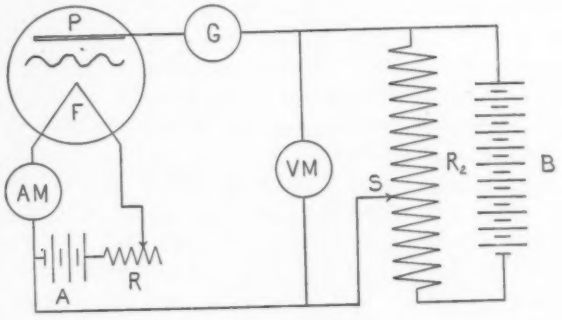

FIG. 1

Any ordinary tube employed in radio may be used to study the properties of the thermionic vacuum tube. In the experiments performed, use was made of a UV201 Radiotron. We may first consider it as a two-electrode tube. The effect discovered by Edison may be observed by lighting the filament and connecting the plate and the negative terminal of the filament

with a sensitive galvanometer. It is more convenient, however, to give the plate a potential and to use a moderately sensitive galvanometer. The connections are shown in Fig. 1. The filament F of the tube is connected in the usual way with a storage battery A, an ammeter AM, and a rheostat R^1. To give a varying potential to the plate a so-called voltage divider may be employed. This is simply a sliding contact tubular rheostat R_2 of a thousand or more ohms resistance. A 45-volt battery B is connected directly across its terminals. The plate P of the tube is then connected to the positive terminal of the rheostat, and the negative terminal of the filament is connected to the slider S. A suitable voltmeter VM is also connected to the positive terminal of the rheostat and to the slider. Thus, by moving the sliding contact along the coil of the rheostat, any voltage can be tapped off and applied to the plate, and it can be measured by means of the voltmeter. For lecture demonstrations a small suspended coil galvanometer G, such as is used in the laboratory, is placed in the plate circuit and a beam of light furnished by a suitable source is reflected from its mirror to a screen or to a wall, in order to indicate its deflections. Any of the devices on the market for furnishing a parallel beam of light may be used. A beam of sunlight, when available, is also satisfactory. For quantitative work in the laboratory, a millamimeter or a calibrated galvanometer (with or without a shunt) is used.

When the filament of the tube is cold no current will flow in the plate circuit however great the voltage applied. When the filament is lighted, it will be noticed that as the positive plate voltage is gradually increased the galvanometer deflection increases, slowly at first, then more rapidly, and finally it remains unchanged. The filament current should be adjusted so that with the maximum plate current the light spot remains on the screen. If we start again with a little higher filament temperature, we get similar deflections, but in this case the maximum deflection has a larger value. On the other hand, if the experiment is repeated, making the plate negative instead of positive, there will be no deflection of the galvanometer whatever the filament temperature or plate voltage. It is easy to understand what takes place in the tube. The positive plate attracts the electrons emitted by the hot filament. As the plate

voltage is increased more and more electrons are drawn over, thus increasing the plate current. As over six billion billion electrons per second are required to furnish a current of one ampere, it is evident that the current actually obtained will be quite small. The maximum or saturation current will be reached when all the available electrons are drawn to the plate. Increasing the plate voltage will have no further effect. According to Richardson this saturation current has the value

$$i = a\sqrt{T}\, e^{-\frac{b}{T}}$$

where i is the current in amperes, T is the absolute temperature of the filament, e is the base of the Napierian system of logarithms, and a and b are constants. For tungsten in a vacuum of less than 10^{-7} mm. of mercury, Langmuir has found the following values: $a = 2.36 \times 10^7$; $b = 5.25 \times 10^4$. When $T = 2000^0$ the current i is equal to .0042 amperes per square centimeter of surface. No current will flow when the plate is negative, since the latter repels the electrons emitted by the filament.

Suppose now that the plate voltage is kept constant and the filament temperature is gradually raised by increasing the current through it. The galvanometer deflection will increase as before and finally become stationary again, indicating a saturation current. As the temperature of the filament is raised, more and more electrons are emitted. They crowd the space between the latter and the plate, until finally the repulsion they exert on the electrons near the filament becomes in many cases greater than the attraction of the plate itself, so that only those with high velocities are able to get through. In this case the plate current is said to be limited by the negative space charge. This space charge is an important characteristic of the tube and has been studied by Langmuir and others. In the laboratory the variations of the plate current with different plate voltages and different filament temperatures may be studied in detail with the arrangement just described. In the first case, the plate voltage is increased by regular steps until the saturation current is reached. Plate voltages are then plotted as abscissae and plate currents as ordinates. This is done for different values of the filament current. In the second case, successive filament currents and the corresponding plate currents are measured for a given plate voltage and then plotted.

Curves such as those shown are obtained. They bring out clearly the action of the tube when two electrodes only are used.

In 1907 Dr. Lee DeForest of New York introduced the third electrode in the tube, between the filament and the plate. This is the well-known grid, which usually takes the form of a flattened spiral of fine wire. This simple addition revolutionized the thermionic vacuum tube and, as Van der Bijil says, made of it "A device of tremendous potentialities—one that can justly be placed in the same category with such fundamental devices as the steam engine, the dynamo, and the telephone." The special function of the grid is to modify or control the plate current. By giving it a positive or negative potential, it is possible to vary the plate current through wide limits without changing either the plate voltage or the filament current. Moreover, a minute amount of energy expended upon the grid can produce considerable energy changes in the plate current. This action of the grid is due to the effect it exerts

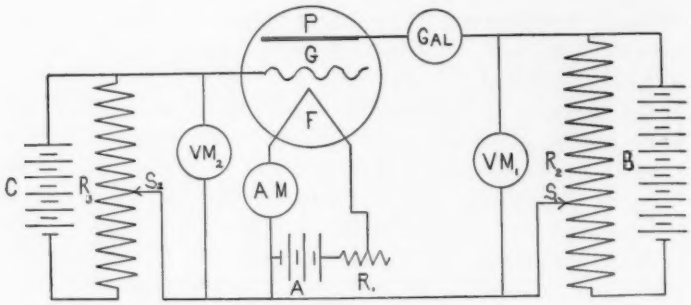

FIG. 2

upon the negative space charge. When it is negative, it increases equivalently the space charge, thus diminishing the plate current. When it is positive, it lessens the effect of the space charge, thus increasing the plate current. To demonstrate this, a circuit is arranged as in Fig. 2. The filament F and plate P are connected with their respective batteries and meters, as in Fig. 1. A second voltage divider is needed. One

or two dry cells C are connected across the terminals of a high resistance sliding contact rheostat R_3 similar to R_2. One end of this rheostat is connected to the grid G, and the sliding contact S_2 is connected to the negative terminal of the filament. A voltmeter VM_2 connected in the usual way serves to measure the potential applied to the grid.

With a given filament current the plate is given a value below its saturation point by proper adjustment of the plate voltage. By means of the sliding contact S_2 a fraction of a volt is put upon the grid. If the latter is made positive there will be an immediate increase in the galvanometer deflection; if it is made negative there will be a decrease. If the negative potential is further increased the plate current can be reduced to zero. This action of the grid can be best studied in the laboratory by obtaining characteristic curves similar to those already described for the two-electrode tube. The filament current and plate voltage are kept constant, and the plate current is measured by means of a milliammeter or galvanometer for different values of the grid voltage. The latter are then plotted as abscissae and the former as ordinates. Similar data are obtained for different plate voltages. Curves for the radiotron employed were shown. They show clearly that, provided the current is not near its saturation point, a small change in the grid voltage produces a considerable change in the plate current. A considerably larger change in the plate voltage would be required to produce the same effect. In other words, the tube possesses an amplifying power which is one of its most important and valuable properties. The ratio of the plate and grid potentials which produce the same change in the plate current is called the amplification factor or coefficient of the tube. Thus on one of the curves shown for the UV201 Radiotron, when the plate voltage was 40, a change of 0.5 volts on the grid produced the same change in the plate current as a change of 4.5 volts on the plate. Under these conditions, therefore, the amplification factor is equal to nine. As a matter of fact its value varies somewhat with the plate and grid potentials.

Since a given electromotive force applied to the plate of a tube causes a definite current to flow, we may, by referring to Ohm's law, speak of its resistance, or to use the more common

term, its internal plate resistance. In the case of a metallic conductor, the resistance, neglecting temperature effects, remains constant, and, if impressed voltages are plotted as abscissae and the corresponding currents as ordinates, the reciprocal of the slope of the straight line obtained will be equal to the resistance. If we plot the same data for a vacuum tube, a curve and not a straight line is obtained, as has already been pointed out. Its slope varies showing that the resistance does not remain constant. However, the reciprocal of the slope at any point is equal to the corresponding resistance. One of the curves of the UV201 Radiotron shows that with no voltage upon the grid, a change of 5 volts on the plate causes a change of 0.0000387 amperes in the plate current. The corresponding internal plate resistance is therefore equal to 12900 ohms. When the grid is used it can be shown that the resistance is equal to the reciprocal of the slope of the grid voltage-plate current curve multiplied by the amplification factor.

As is well known, when the effect produced upon the plate current by a given potential upon the grid is not sufficient for the purpose intended, one or more additional tubes or amplifiers may be employed. Such combinations are of great importance in radio and in various scientific investigations. There are several possible circuits. We may take one of the simplest cases. Suppose that the single tube in Fig. 1 does not produce a sufficient effect. Instead of sending the plate current through a galvanometer or telephone or other suitable detector, it is sent into the primary of a small step-up transformer. The secondary of the latter is connected to the grid and to the negative terminal of a second tube, which has a suitable battery in its plate circuit. The stepped-up voltages communicated to this grid produce corresponding magnified variations in the second plate current A detector may be used for this current, or it may be sent into the primary of a second transformer connected in a similar way with another tube. With several tubes very high amplifications may be obtained. However, there is a practical limit to the number that may be employed as, on account of reactions in the circuits, oscillations are set up which produce howling.

By means of amplifiers minute quantities of energy may be made to produce very considerable effects, as, for example, in

operating loud speakers or relays controlling various devices. Various experiments have been devised to show this action of the tubes. Thus, for example, Dr. W. R. Whitney, in a lecture delivered at the Cincinnati meeting of the American Association for the Advancement of Science, showed how, using amplifiers, a static charge and the output of a photoelectric cell could control a lamp circuit. A similar effect may be shown without amplifiers, using a single Radiotron tube and a Weston Relay (Model 30). The latter is essentially a sensitive Weston movement whose moving coil has a contact arm which opens or closes an external circuit. The circuit is arranged as in Fig. 3.

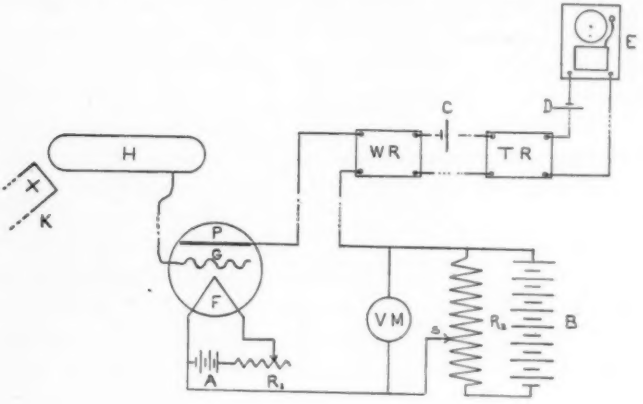

FIG. 3

The filament F of the tube is connected with the battery A and rheostat R, as in Fig. 1. Two 45-volt batteries B are connected to the voltage divider R_2. The voltage applied to the plate by the sliding contact S may be measured by means of the voltmeter VM. The Weston Relay WR is put in the place of the galvanometer in the plate circuit and is connected with an ordinary telegraph relay TR in series with one or two dry cells C. This second relay is connected in series with an electric bell E and a couple of dry cells D. The grid G is connected by means of a wire with an insulated brass conductor H, such as is used in electrostatics. With the normal filament current, the plate voltage is now regulated so that the plate rheastat R, as in Fig. 1. Two 45 volt batteries B are con-

current is not quite able to operate the Weston Relay. A glass rod is then rubbed with silk and brought near the insulated conductor. A negative charge will be induced on the nearer side of the conductor and a positive charge on the farther side. The latter is communicated to the grid and neutralizes the negative space charge sufficiently to enable the plate current to operate the Weston relay. The latter then operates the telegraph relay, which in turn closes the bell circuit. The glass rod will do this when several feet away from the conductor. The discharge of the plate of an electrophorus will also actuate the relay when some distance away.

A word may be said about another property of the thermionic vacuum tube, namely its ability to produce undamped oscillations in a suitably connected circuit. Oscillations from a half

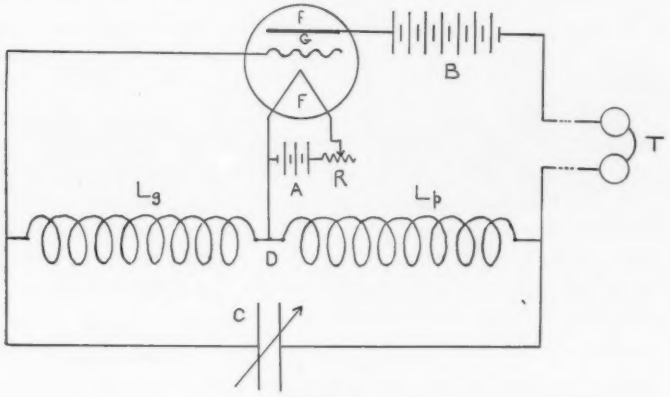

FIG. 4

a cycle a second to a number of million per second are possible. A circuit containing inductance and capacitance is necessary. It has a natural period of oscillation whose frequency is given by the equation $n = \frac{1}{2\pi}\sqrt{LC}$, where L is the inductance in henrys and C is the capacitance in farads. In the experiment shown the circuit was arranged as in Fig. 4. Other combinations are possible. The filament of the tube is connected as before with a storage battery and rheostat. Two 125 millihenry inductance coils are connected together with their planes parallel. The common terminal D is connected

to the negative terminal of the filament. A decade condenser giving from 0.01 to 1.1 microfarads is connected in parallel across their free terminals. The free end of the coil Lg is connected with the grid, and the free terminal of the coil Lp is connected through a loud speaker and a 45-volt battery B with the plate P of the tube. It may be desirable to put a condenser across the terminals of the loud speaker. This can best be determined by trial. If an oscillation is started, for example by closing a key in the plate circuit, or even by closing the filament circuit, the grid will have an alternating potential produced on it by means of the coil coupled with it. This alternating potential will cause a pulsating current in the plate circuit. When the constants of the circuit are properly chosen this current will have the same period as the natural frequency of the circuit and, by supplying energy losses will keep up undamped oscillations. L and C are made sufficiently large to give audio-frequency oscillations. The loud speaker emits a musical note whose pitch can be varied by changing either L or C.

The thermionic vacuum tube has thus far given ample evidence of its value and usefulness as an instrument for scientific research and promises even greater achievements in the future. A few of its applications may be mentioned in passing. Since the two-electrode tube only allows current to pass when the plate is positive, it can be used as a rectifier for high-frequency oscillations. In 1905 Fleming in England used it in this way as a radio detector instead of a crystal. In the Coolidge X-ray tube the electrons emitted by the hot filament travel towards the tungsten plate with great velocity on account of the high values of the electromotive force employed, and by their impact produce X-rays. The tungar rectifier is also an application of the two-electrode tube. However, the ions furnished by a small amount of argon in the tube make a larger current possible than that caused by the electrons alone. The functions of the three-electrode tube in radio transmission and reception are familiar. It also serves as a relay in wire telephony, making possible the transmission of speech across the continent. Receiving tubes and amplifiers are now used to record distant time signals upon a chronograph in longitude determinations. The passage of alpha particles through

air and the impact of electrons upon a plate have been made audible. Tolman and his associates have used the tubes to measure the minute current produced by the slight relative motion of the electrons in a metallic conductor when the motion of the latter is suddenly changed. Whiddington, in England, has devised an ultra-micrometer using tubes which it is claimed can indicate distances of the order of magnitude of atomic diameters. In the domain of biology, Bovie and Chaffee of Harvard have employed amplifiers to study the electrical response of the retina under the stimulation of light.

An Inexpensive Footlight Dimmer.

W. G. WHITMAN.

IT frequently happens that an amateur theatrical performance is given in the school hall, and that the science instructor is called upon to act as electrician.

It matters not how many lights are connected in parallel for the footlights, provided the total current is within the capacity of the circuit and connecting wires. There may be a call to have the lights gradually decrease in intensity. This is easily done with the regulation dimmer, which is not commonly in the science equipment, and which is too expensive to buy just for this purpose. Exactly as good results may be obtained, however, at no expense, with materials at hand in the laboratory.

The essential device used to reduce the voltage through the lights is a salt cell connected into the circuit. Place a copper plate several square inches in area in one end of a hard rubber photographic tray. This plate is fixed in place. The tray should be fifteen inches long. Have another copper plate fastened to a wooden handle to facilitate moving it back and forth in the tray. One wire from the source of current goes directly to the footlights. The other wire goes to the fixed copper plate in the salt cell. A wire from the movable copper plate goes to the footlights to complete the circuit. Pour a 3 per cent solution of sal ammoniac or common salt into the tray, filling it at least one inch in depth. When the circuit is closed the lamps will burn at full power if the two metals are near together, but the brightness decreases as they are separated.

If the length of the tray is insufficient to give the desired dimness, the solution may be in part exchanged for water, or the movable plate may be partially removed from the liquid. A large battery jar with dilute sulfuric acid may be used instead of the tray of brine, if desired. A little experimenting will show the right strength of acid solution to use.

It is desirable, but not necessary, to have a shunt switch, which may throw the dimming apparatus wholly out of the circuit when full power of the lights is desired for any length of time.

Outdoor Summer Study For The Teacher.

Emma L. Kemp, Lincoln High School, Jersey City, N. J.

At a dinner of the New Jersey Science Teachers Association, two teachers were discussing their vacations of the previous summer. One had a long canoe trip on the lakes of the Adirondacks, the other hiked part of the Long Trail of the Green Mountains of Vermont. A high school principal sitting between them remarked that science teachers have more enjoyable vacations than teachers of other subjects, because they know so much about things out of doors. But do they know so much of these things? The training of some teachers is such that they have not much of this knowledge, but if fond of the out-of-doors they become curious and want to learn. For example, a teacher who specialized in chemistry and physics in college, may have had no advanced work in biology (or, I find that even those who had considerable college work in biology, sometimes know comparatively little about what they find in the field), and in teaching about plants and animals in general science, he is likely to find that he does no know much more than he tells his pupils.

How is the teacher to make up for this deficiency, and improve his course in general science? There are always books, scientific journals and magazines that may be read. If in or near a large city, lectures may be heard at the meetings of the various scientific societies, or he may take extension courses at universities. But it is hard to get the time, and some lack the strength to do much of this outside work along with their regular

teaching. There is the summer vacation period. But many teachers shrink from the idea of studying when they ought to be resting. They long to be out of doors. What better place to study some sciences than out of doors, in the fields and woods and on the mountain tops? What better plan for teachers to remain human than to enjoy the sociability of a field course and have once more the viewpoint of the pupil? What better brush to remove the cobwebs from the brain than the gymnastics of acquiring new facts? What better way to renew one's health than to shake off the restraints of the classroom and desk and enjoy the freedom of the open air?

Following is a partial list of science courses of two kinds: those in which the greater part of the time is spent in the field, and those in which the greater part of the time is spent in lecture hall and laboratory, with some time in the field.

LIST OF INSTITUTIONS OFFERING SUMMER COURSES WITH FIELD WORK.

1. Rutgers University and the State University of New Jersey.
   At Brunswick N. J.
   Field Botany.
   General Geology and Physiography, with field trips.
   Nature Study, with field trips.
   Field and Laboratory Studies of Selected Animal Types.
2. Columbia University, N. Y.
   In Rocky Mountain, Yellowstone, and Glacier National Parks.
   Field Work in Physiography.
   In the Catskill, Adirondack, Green, and White Mountains, Lakes George and Champlain. Field work in Physiography.
   In Virginia and West Virginia.
   Field work in Physiography.
   In camp near Laramie, Wyoming.
   Field course in the Geology of the Rocky Mountains.
   At New York City.
   Elementary Historical Geology, with field trips.
   At Woods Hole, Mass.
   Field course in Zoology (see below).
3. New York University.
   At New York City.
   Field course in General Physiography and Geology.
4. The Biological Laboratory, Cold Spring Harbor, N. Y. (Long Island).
   Field and Systematic Botany.
   Field Zoology.
5. Marine Biological Laboratory, Woods Hole, Mass.
   Field courses in various branches of Zoology.
   Field course in Botany, algae only.
6. Cornell University, Ithaca, N. Y.
   Geology field course.
   General and special courses in Botany with field trips.
   Trees and Shrubs, Forestry, etc., with field trips.

General Nature Study, with field trips.
Ornithology, with field trips.
In Pine Barrens of New Jersey.
Field Entomology.

7. Ohio State University.
At Lake Laboratory, Put-in-Bay, Ohio.
Field course in Botany.
Field courses in Zoology; Embryology, Entomology, Ichthyology, Ornithology.

8. Indiana University.
At the Biological Station, Winona Lake, Indiana.
Field courses in various branches of Zoology.

9. University of Michigan.
At Ann Arbor, Michigan.
Geography and Geology with field trips.
Landscape Design, special course in Trees and Shrubs, field trips.
At the Biological Station, Douglas Lake, Michigan.
Field Zoology; special courses in Ichthology, Lymnology, Entomology, Ornithology, Herpetology and Mammalogy.
Field Botany; special courses in Crytogams, Bryophytes, Ecology, Plant Anatomy and Geography, Systematic Botany.
At camp in Southern Kentucky.
Field Geography, Geology, Physiography.

10. University of Iowa.
At Lakeside Laboratory, Milford, Iowa.
Research in Botany and Zoology.

11. University of Wisconsin.
At Madison, Wisconsin.
Teaching of Botany, with field trips.
Animal Biology, with field trips.
General Geology, with field trips.
Physical Geography, with field trips.
Classification of Seed Plants, Saturday excursions.
Native Trees and Shrubs, Saturday excursions.
Field Zoology.
St. Lawrence Section.
Field Geology, open to men only.
In camp at Devil's Lake, Michigan.
Field Physiography and Geology, open to men only.

12. University of Colorado, Boulder, Colorado.
In camp at Mountain Laboratory.
Field courses in Geology.

13. University of California, Berkeley, Cal.
Historical Geology, with field trips.

A very enjoyable and profitable six weeks in the summer may be spent taking one of the field courses at the Biological Laboratory at Cold Spring Harbor. The laboratory is situated on the north shore of Long Island, N. Y., on Cold Spring Harbor, about three miles from Long Island Sound and at the mouth of the outlet from a chain of small lakes. Thus, with the aid of a bathing suit and occasionally the *Beagle,* a small motor-boat, the classes study plant and animal life of both fresh and salt water. One of the most interesting groups of

marine life is the algae, of which the botany class collects a large variety. On land, the field of study extends to the neighboring woods, the prairie-like Hempstead Plain, the misnamed pine barrens, the region of Lake Ronkonkema, the sand dunes of the south shore, and many large cultivated estates and a large nursery. Regions some distance from the laboratory are reached by motor bus, but shorter trips are made on foot, so the work is fairly strenuous. As this is only a summer school, the instructors come from many different colleges and universities. The pupils come from many different states, as, in a class of fourteen in botany last year, eleven states were represented. The school is small enough for pupils to become well acquainted with each other and with the instructors, and the most cordial and sociable spirit prevails on the daily field trips and at the work in the laboratory. Nor is play omitted, as there are opportunities for swimming, evening beach parties, at least one all-day picnic to the south shore, community singing once a week, and a clam-bake as the grand finale. As for using the information acquired in such courses, that is always possible in general science. The method used to teach my pupils to identify the trees of their city (described in this journal for last November) was adapted from that used in Field Botany at Cold Spring Harbor.

Incidentally, one may study the geology of Long Island. This is concerned mainly with the terminal moraine of the Great Ice Sheet and conditions resulting from it. Of much more varied character is the region in which field courses in geology of the University of Colorado are given. These are given at Science Lodge, at an elevation of 9,500 feet in the Rocky Mountains, 28 miles from Boulder. Courses are offered to beginners, advanced students and graduate students. The region affords first-hand study of metamorphic and igneous rocks, ore deposits, glaciers, and various phases of physiography.

For the first three weeks of the course students live in a co-operative camp and study in the field and at the mountain laboratory, with frequent evening campfire conferences. The field work means rough walking and climbing and going into ice and snow. The air is always cool and invigorating and the beauty of the views beyond description. The fourth week

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is spent touring the Rocky Mountain National Park and studying its geology. Thus one becomes closely acquainted with one of the finest regions of the country.

Sometimes teachers of general science become impatient with the general nature of the work and feel the need of specializing for their own advancement. But if one wants to know more than he tells his students in every branch of science, and is interested in some of the big questions of science, broadening one's knowledge is equally important. This is well illustrated in two articles that appeared in the *Scientific Monthly*, "The Origin of Life," by Prof. Charles B. Lipman, and "Why I Teach Evolution," by Prof. William Patten. Not one science, nor two nor three, but the whole field of science is drawn upon in these brief papers. The list of summer field courses offers graduate courses to the teacher who would specialize and elementary courses in sciences with which he may be comparatively unfamiliar.

Summer Courses in Science.[1]

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Biology in Senior High School. *W. L. Eikenberry*

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The Teaching of High School Chemistry. *Charles J. Pieper*

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The Teaching of General Science in the Junior High School. Class and laboratory methods and equipment. Field trips, texts, and content of typical courses. *H. A. Carpenter*

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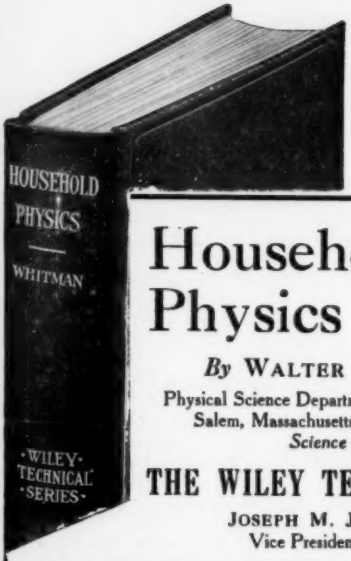
1 Additional courses are listed on p. 203, in the "Quarterly" for March, 1925.



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Chemistry for Boys and Girls—Greer & Bennett—844 pages—159 illustrations—Allyn & Bacon.

This is a most interesting book. It is written in simple language and in a style to capture both boys and girls. There seems to be nothing omitted unless it be a treatment of mathematical chemistry, and even problem work is given in the appendix. The everyday applications of chemistry are abundant and include those which figure most conspicuously in the daily lives of boys and girls. Topics of home chemistry and of industrial chemistry are included with the very essential theoretical side of the subject. The large amount of ground covered makes it a particularly good reference work for general science classes, although its primary function is as a text for the high school chemistry course. Each chapter is introduced with a list of questions to arouse the pupils' interest in the contents of the chapter. Each chapter ends with a summary and a list of review questions. One hundred seventy-three experiments are outlined in the text and there is an appendix of thirty-six pages.

The Mental Growth of the Pre-School Child—Arnold Gesell—447 pages—Illustrated—The Macmillan Company.

This book is the product of six years of investigation and experiment with normal children. "The basic data furnishes an outline of the psychology of infancy by bringing into systematic view cross-section behavior pictures of the ascending stages of development." It is expected that the applied phases of the volume will be serviceable in the making out of estimates of the developmental status of young children. The four parts of the volume are entitled: Introduction, Norms of Development, Comparative Status of Development, Developed Mental Diagnosis and Supervision. The book will interest parents as well as special workers in the field.

Early Steps in Science—Webb & Didcoct—691 pages—298 illustrations—D. Appleton & Company.

This book has a well chosen title and follows the present trend of general science in covering *home* and *community* problems. The chapter titles indicate very well the topics covered. They are: The Homes in Which We Live, The Clothing We Wear, The Community in Which We Live, How Men Travel and Communicate, Worlds that Travel Through Space, The Weather Day by Day and Its Causes, Forms of Land and Water, Living Creatures of the Earth, Man as a Living Creature, The Work of Continuing the Species. Each chapter ends with a list of helpful review questions. The book is written for the first year of high school and offers a fine list of material. It is well written and finely illustrated. It is a book that cannot fail to make a strong appeal to pupils.

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Food Facts for Every Day—Florence Winchell—109 pages—60 illustrations—J. P. Lippincott Company.

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Safety First for School and Home—Harriet E. Beard. 223 pages. The Macmillan Co.

This is a very timely book. Never before has there been such need of safety education in the schools. In part one the chief subjects discussed are fire, falls, poisons, electricity, railroads, street cars and automobiles. Part two gives specific directions for undertaking the work in each of the grades. There is a good chapter on first aid and an excellent fire prevention play. Such a book as this ought to be taught in every elementary school.

Science for Boys and Girls—M. Louise Nichols—326 pages—236 illustrations—J. P. Lippincott Company.

This book is well adapted to young children, in the simplicity of material offered. It is separated into two parts. Part one deals with biological topics, and part two with physical topics. The plant and animal studies cover growth of plants, storage of food, spring flowers, trees in spring, fall flowers and fruits, harmful and useful insects, birds, parents and children. The physical science topics include measuring and weighing, water, atmosphere, machines, heat and fire, mortar, acids and alkalies, soap, elements, electricity and magnetism, sound. There is a final chapter on the value of science.

The book is well illustrated and attractive in its general appearance. Some chapters have experiments to accompany them. A few helpful questions are listed at chapter ends.

Southern Field Crops—Revised edition—John F. Duggar—444 pages—163 illustrations—The Macmillan Company.

This volume covers agricultural research and recent practices in agriculture in the Southern States. It treats of cereal grains, cotton, and various field crops, as peanuts, sugar-cane, sweet potatoes, tobacco, hemp, and the sorghums. The treatment given is splendid; facts are simply told; selection of material is admirable. Laboratory exercises and a fine list of references accompany each topic. There is a glossary of 16 pages at the end of the book.

Biology and Human Life—B. C. Gruenberg—603 pages—243 illustrations—$1.72—Ginn & Company.

This book covers the same general ground as the authors "Elementary Biology," and yet it differs in organization and in a considerable amount of subject material. It conforms to the recommendations of the N. E. A. Commission on "Reorganization of Science in Secondary Schools." The main divisions of the book are: Getting Acquainted with Life. Keeping the Body in Condition, Control of the Body, Control of the Environment for Health, Biology of Wealth, and Conservation. Chapters open with a few thought-provoking questions and end with a list of questions and with reference readings. It impresses one as an interesting and a valuable work. It is surely filled with practical material that can be used in one's every-day life.

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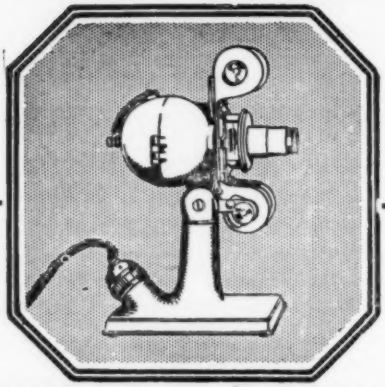

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